PATENT SPECIFICATION

DRAWINGS ATTACHED

1,159,390

1,159,390

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Int. Cl.:—H 01 r 9/16

COMPLETE SPECIFICATION

Electrical Terminals and method of making the same

We, RITTER PFAUDLER CORPORATION of 1100 Midtown Tower, Rochester, New York 14604, United States of America, a corporation organised and existing under the laws of the State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electrical terminals for use in connection with thin film electrical circuit encapsulated within a dielectric material, and to methods of making electrical devices incorporating such terminals.

The films of such circuits are very thin and will not withstand physical abuse or arcing without either damage to, or destruction of, the circuit. Consequently, thin film printed circuits, for the purpose of protecting the circuit, are commonly encapsulated within a protective material such as organic resins or foams such as poly-urethane. Most commonly, of course, these encapsulating mediums have dielectric properties, the effectiveness of which depends upon the dielectric material used.

Conventional methods of connecting electrical terminals to an encapsulated electrical circuit are not suitable for use with thin conductive film circuits because of the fragility of the circuit, and, in fact, conventional terminals cannot be used, i.e. low temperature solder would melt at the operating temperature of the device; high temperature solder cannot be encapsulated; mechanical connections such as bolts result in leaving interstices in the glass and because of having to pass through the base would result in corrosion and wearing of parts, ultimately resulting in increased electrical resistance.

While, as previosly mentioned, it is known to encapsulate electrical circuits and terminals, including printed conductive films in materials such as poly-urethane resins, the encapsulation of such circuits and terminals within glass or glass-ceramic compositions has many advantages. Moreover, the application or bonding of the encapsulating glass to a relatively strong rigid substrate has many advantages in the production of units such as those mentioned above. However, the glass or use of glass-ceramic compositions and the bonding of the glass to the metal substrate introduces many problems.

In accordance with one aspect of the present invention, there is provided an electrical device of the type including a thin film electrically conductive circuit encapsulated within a dielectric protective layer, said layer including a lower cover coat and top encapsulating coat and said circuit being positioned between said coats and being supported by said cover coat, said device having an electrical terminal connected to said circuit and extending through and beyond the surface of said encapsulating coat, in which said terminal comprises a wafer in contact with said circuit and a post connected to said wafer and extending beyond the outer surface of said layer, said wafer being at least partly embedded in said top coat and having such configuration and properties as to inhibit said terminal and said circuit from moving through said cover coat during application of said encapsulating coat.

Preferably, the encapsulating medium is a glass, such as a dielectric glass, and the circuit is a conducting film.

Preferably, the wafer is circular in plan and the post is flexibe. The wafer may be of some ten mils thickness, and have apertures therein through which the encapsulating medium extends to firmly bond the wafer and post in position.

In accordance with another aspect of the present invention, there is provided a method of connecting an electrical terminal to a thin film electrical circuit which circuit is to be encapsulated within a layer of dielectric protective material comprising the steps of providing a cover coat of said material, applying said

thin film electrical circuit on top of said cover cost, connecting a terminal comprising a wafer and a post to said circuit, with said wafer being in contact with said circuit and applying an encapsulating coat of said material over said circuit and cover coat and at least partly over said wafer, to encapsulate said circuit within said material, said wafer having such configuration and properties as to inhibit said terminal and said circuit from sinking through said cover coat during application of said encapsulating coat.

The terminals of this invention and their application to and in conductive relation with an electrical circuit may have application wherever a thin film circuit is encapsulated within a dielectric medium. For example the terminals of this invention may be employed in connection with capacitance or inductance circuits. The terminals and method of this invention have been more particularly developed for use in connection with heating devices wherein the electrical circuit is a resistance circuit encapsulated within glass-ceramin dielectric materials.

The encapsulating medium and the encapsulated electrical circuit, together with its terminals, are preferably applied or bonded to a substrate to give strength and rigidity to the assembly. While certain ceramic materials may be employed as the substrate in connection with the production of certain end products it is primarily envisaged that the electrical circuit be applied to a metal substrate. While other metals, such as aluminium, may be used as the substrate as will later be discussed, it is believed that the invention has its widest application where the substrate is mild sheet steel. The completed assembly with proper selected electrical characteristics may be used in connected with the production of space heaters or heaters for special industrial and other purposes, electrical appliances such as toasters, frying pans, coffee pots, warming ovens, and trays, and many other devices of a similar nature.

Other features of the invention will be apparent from the following description of certain embodiments thereof which are given by way of example and are to be taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a sectional view showing a resistance heater having an encapsulated resistance circuit with a terminal in accordance with the invention in conducting relation with the resistance circuit and partially embedded in an encapsulating coating with the assembly bonded to a metal substrate;

Fig. 2 is a top plan view of Fig. 1;

Fig. 3 is a top plan view of the terminal disc or wafer shown in Figs. 1 and 2;

Fig. 4 is an elevational view of the terminal comprising the disc and the post welded to the disc;

Fig. 5 is a top plan view of a second embodiment of terminal in accordance with the invention and illustrating a method of making the same;

Fig. 6 is a side elevation of Fig. 5 prior to bending the post so that it extends substantially normal to the disc;

Fig. 7 is a view showing a further embodiment in which the post extends through the encapsulating glass layer and outward through an opening in the substrate metal; and,

Fig. 8 is a view similar to Fig. 4 showing a crowned or domed disc which appears to eliminate or at least minimize certain causes of failure when a flat disc terminal such as is shown in Fig. 4 is used.

Referring first to Fig. 1, the terminal assembly, generally indicated by the numeral 11, is electrically connected to a circuit 12 embedded in glass, as will presently appear, carried by a metal substrate 13. Preferably the metal substrate is a low-carbon sheet steel. While alloys of steel may be used and other metals and their alloys may also be employed, mild steel is the preferred substrate as the backing for the assembly in most cases. The substrate metal should preferably be rigid and unyielding. If a soft metal or material other than a metal is employed as a substrate, it should be a formable material of substantially rigid character adapted to maintain its shape under elevated temperatures. The assembly can then be subjected to relatively rough treatment when incorporated in, for example, a space heater or in cooking or heating utensils.

Mild sheet steel is also the preferred substrate metal because it is not distorted at the temperatures at which the glass, when encapsulating the printed circuit, should be fired on the metal substrate. These temperatures range from 1550°—1750°F. The metal substrate 13 is preferably preformed to substantially the size and shape desired in the completed heating unit. Thus, for example, if a frying pan is to be manufactured, the metal substrate would be shaped or stamped substantially to the desired shape of the finished frying pan.

After conventional surface preparation of the sheet steel substrate, a cover coat of dielectric glass 14 is bonded to the metal substrate 13. The cover coat 14 may be bonded directly to the metal substrate but in most instances it is desirable to interpose a ground coat 16 between the glass cover coat 14 and the metal substrate.

The cover coat 14 and the ground coat 16, if one is used, are fired on the metal substrate at a temperature between 1550°—1750°F; 1600°F. being a good average value. These coatings should have a dielectric strength sufficient so that the completed heating unit may operate at temperatures up to 800°F., and preferably up to 1000°F., without undue electrical leakage. However, the invention finds its

largest field of application in units where the operating temperature is 400°—450°F. It is sufficient for the purposes of the present invention to state that the cover coat 14 may be glass crystallized in situ as disclosed in U.S. Specification No. 3,368,712; a glass crystallized by incorporating in the glass mix discrete particles as disclosed in U.S. Specification No. 3,051,589; or some other special dielectric glass.

After the cover coat 14 has cooled or substantially solidified, the resistance circuit 12 is applied over the cover coat 14 in a circuit pattern as illustrated in Fig. 2. The circuit ends are then connected to the terminals 11 in a manner which will presently be described.

The circuit 12, shown in Fig. 2, is preferably a printed circuit. Such printed circuits are well-known in the art and are commonly used in the electronics fields. They are made of finely ground metal particles particularly, for example, silver particles, a binding cement, and finely ground glass particles. The silver or conductor mix is available in a commerical form and is applied by a silk screen process which is also well-known in the art. After the printed circuit has been applied to the cover coat 14, the entire assembly is fired at a temperature of between 1550°—1750°F., preferably 1600°F., to fuse the silver printed circuit to the glass. This fusion of the electrical circuit with the cover coat 14 causes the cover coat to become somewhat flowable, and the silver circuit being somewhat higher in specific gravity than the glass causes the silver circuit to very slightly embed itself in the cover coat 14. During this firing period the printed circuit may be said to "float" on, or be buoyant with respect to, the dielectric cover coat 14. The slight embedding of the printed circuit, which may be only a few thousandths of an inch, aids in minimizing the watering of particles of silver out of the circuit pattern.

At the ends of the circuit, as illustrated in Fig. 2, the circuit is enlarged in area to form substantial enlarlements or "islands" 17 which may be generally circular to receive the bottom faces of the terminals 11. The purpose of the enlarged spots or "islands" of silver 17 is to provide an area for the reception of discs 18 of the terminals. Good electrical contact is obtained between the discs 18 and the enlarged areas 17.

Each terminal 11 comprises the disc or wafer 18 and a post or stem 19. The two terminals 11 are placed on the ends or "islands" 17 of the printed circuit. After the circuit and cover coat have solidified, a top encapsulating coat 21 is applied over the printed circuit and over the discs 18 of the terminals 11 as shown at 20. The terminals 11 are attached to the conductive film by cementing the discs or wafers to the enlargements 17 of the circuit. The circuit is then fired and the volatile ingredients of the cement volatilize during firing, the remainder of the conductive cement being indicated by the numeral 22. Next the encapsulating coat is applied over the resistance circuit so that it preferably covers the discs 18 of the terminal and possibly the extreme lower ends of the stems or posts 19.

The encapsulating coat of glass is fused over the entire surface at a temperature of between 1550°F. and 1750°F., preferably at a temperature of approximately 1600°F. The encapsulating coat is a dielectric coating, which may be of crystallized glass formed by crystallizing the glass in situ or by adding discrete particles to the glass mix as set forth above. The cover coat 14, during the firing of the encapsulating coating 21, becomes a soft viscous mass. However, the terminal discs and the printed circuit are submerged in the semi-fluid mass and the cover coat 14 and the encapsulating coat 21 tend to solidify as a unit as they cool, thus completely enclosing and sealing the printed circuit. It is not essential that the terminal discs be completely covered with glass, but it is important that they be firmly anchored in electrical contact with the printed circuit and in the mass of glass against any accidental displacement.

Referring now to Fig. 3, it will be seen that the disc or wafer 18 of the terminal 11 is circular in plan. The purpose of making the wafer 18 circular and extremely thin is that when the encapsulating coat 21 or glass is fired and later cooled, forces are set up between the wafer and the surrounding glass. To minimize these forces, the metal of the wafer should have a low coefficient of expansion. It has been found that "Inconel X" marketed by International Nickel Company is suitable for the purpose (Inconel is a Registered Trade Mark). Regardless of the metal chosen the metal will expand more rapidly when heated than the encapsulating glass and upon cooling will contract more rapidly. In Fig. 3 the direction of these forces is indicated by double ended arrows. During the expansion of the metal of the wafer such expansion occurs radially outwards. Thus the forces, because of the circular configuration of the wafer, are exerted equally from all sides outwards and inwards from the axis of the wafer.

It has further been found, as mentioned above, that it is desirable to make the disc or wafer extremely thin in cross-section. A disc five to ten thousandths of an inch in thickness has been found suitable. Indeed, discs as thin as three mils in thickness have been used. Generally, the wafer should be as thin as it is possible to make it while still providing sufficient metal so that it is not distorted in normal handling. An extremely thin disc cuts down the forces generated by expansion and contraction of the disc.

One of the problems encountered is that the terminal being heavier than the glass tends to sink during the last firing of the assembly. If

it sinks sufficiently, it can engage the metal substrate and cause a short-circuit. In fact, if its sinks appreciably, even though it may not engage the substrate, the proximity of the disc of the terminal to the substrate may result in sufficient current leakage to cause failure and destruction of the printed circuit. The wafer should therefore have as large an area possible; should be thin; and the complete terminal should be as light in weight as possible. The terminal will then "float" on, or be "buoyant" with respect to, the cover coat when the encapsulating coat is fired. This buoyancy may be aided by surface tension of the cover coat and its printed circuit. The temperature at which the encapsulating coat is fired is also important. It should be sufficient to render the cover coat viscously flowable not sufficiently flowable to cause the terminal to rapidly sink during firing. Depending upon the glass mix, this range should be between 1550—1750°F., preferably about 1600°F. It has also been found desirable to weaken the discs, for reasons later stated, as for example by providing radially extending slots in the discs or by providing circular cut-outs in the discs, as shown at 26. In Fig. 3 five circular cut-outs are shown extending around the central axis of the disc although the number of cut-outs and the precise manner in which the discs are weakened is optionally variable.

The stem or post 19 is preferably made of twisted or braided conductive wire and should preferably yield when accidentally bumped. The strands of twisted wire are welded to the post or wafer, the weld 27 (Fig. 4) being continuous so that each wire is welded to the disc giving the effect of a multiplicity of welds. The wire and weld should be of metals which will not melt at the firing temperature of 1550—1750°F., and of course the wire should weld easily and firmly to "Inconel X" if that metal is used for the disc. Nickel has been found suitable, but other metals such as silver would also be suitable.

One of the problems encountered in the manufacture of a terminal for the purpose described, is that notwithstanding the fact that the crystallized glass is hard and highly resistant to mechanical forces such as a blow by a hammer, it, in common with all glasses which are subjected to expansion and contraction forces, has a tendency to chip, crack or craze. This tendency is magnified in the glass adjacent to the terminal because of the unequal forces of expansion and contraction set up between the glass and the metal. When these forces are excessive, the terminal will "pop off" the glass. This "pop-off" problem is reduced to practical manufacturing limits by: using metals which have a low coefficient of expansion; using a wafer thin disc; and by weakening it so that it will yield when necessary during the firing and cooling cycle.

The terminal during firing may be said to "float" in the fused glass and while buoyant to a certain extent, its specific gravity is sufficiently greater than that of the glass so that it will maintain contact integrity with the "island" of the printed circuit. The encapsulating glass during firing flows over and embeds the terminal wafer and the lower part of the post and flows through the openings in the wafer effectively locking the terminal in the glass and in electrical contact with the printed circuit.

The encapsulating coat 21 should be as thin as possible to secure maximum heat transfer. Moreover, a thin layer is more resistant to thermal shock. An encapsulating layer in the range of four to five mils is desirable. Where a thermostat or other device is also encapsulated, a thickness in the range of eight to ten mils may be necessary.

In Figs. 5 and 6, there is shown a modification of the terminal in which the stem is in one piece and is preferably made of nickel rod or wire material. The nickel rod is flattened at 31 and welded, as indicated at 32, to the disc 18. After the weld has been made, the free end of the rod is bent upwards substantially at right-angles to the disc. The terminal of Figs. 3 and 4 is preferred because the stem 19 is in effect multiple-welded to the disc and because it is flexible and less likely to be damaged or damage the glass encapsulating coat if accidentally struck in assembly of the heating element in a unit or in shipment.

In Fig. 7 there is shown a further embodiment of the invention wherein the stem 19 of the terminal 11 projects through the "island" of the printed circuit and through an opening 34 in the metal substrate to receive the conductor 36. In some appliances such as a frying pan, it may be desirable to have the frying surface entirely of glass to enable easy cleaning and have the terminals project through the metal substrate.

In Fig. 8 there is shown a modified form and possibly preferred form of terminal disc. It has been found that a percentage of heating units manufactured with a disc in accordance with Fig. 4 fail in service or upon testing. After considerable investigation, it appeared that a large bubble was forming beneath the disc during the firing of the unit to cement the terminal disc to the "island" 17 of the printed circuit. The cause of this bubble is not known for certain. It may be caused by gases released from the base metal bubbling upward through the cover coat 14 and collecting beneath the disc. Alternatively, and this is more likely, the bubble is formed by gases released during firing from the cement on the discs. Whatever may be the cause of the bubble, when a bubble of sufficient size is formed, it occasionally causes the island of the printed circuit to become depressed into the cover coat

14 either into contact with the base metal or sufficiently close thereto to cause excessive electrical leakage.

It has been found that by doming the disc, as shown at 40, the failures are eliminated or at least minimized. When the disc 18 is domed an annular ring 41 of metal is provided and this annular ring provides an air space 42 which is in communication with the holes 26. As mentioned before, cement is applied to the bottom surface of the disc, as indicated at 43. In general an effort is made to apply the cement primarily to the annular ring 41 and minimize or eliminate the application of cement to the underside of the crowned part. Because the cement is applied in an annular ring either no bubble of sufficient size is formed to cause the failures mentioned above or because the gases may collect below the dome and escape through the holes 26 before application of the encapsulating coat 21, it is found that failures due to a bubble of gas below the discs are eliminated or minimized.

In the foregoing description, mild steel has primarily been considered as the base or substrate metal, and firing temperatures in the range of 1550—1750°F. have been envisaged. Such temperatures are below the distortion point of mild steel, although at the higher temperature end of the range some distortion will occur. However, in connection with some products, a different substrate metal such as, for example, aluminium may be used. Aluminium has good conductivity characteristics and is relatively low in cost. However, it cannot be used with firing temperatures in the range set forth above. Aluminium has a melting point in the region of 1200°F. One of the possible uses of the terminal in accordance with the invention is in the production of space heaters where the heating surface is exposed, as for example, base board heaters for home heating. Where the heating element is exposed the temperature at the exposed surface should not exceed 180°F. In such heaters aluminium or one of its alloys and a glass having a much lower firing temperature, that is below the distortion point of the substrate metal, may satisfactorily be used. For example, certain lead glasses, as is well-known in the art, crystallize readily at temperatures below the distortion point of aluminium and in a crystallized state have good dielectric characteristics. Lead glasses, depending upon their composition, having a firing temperature of between 1000 and 1400°F.

WHAT WE CLAIM IS:—

1. An electrical device including a thin film electrically conductive circuit encapsulated within a dielectric protective layer, said layer including a lower cover coat and a top encapsulating coat and said circuit being positioned between said coats and being supported by said cover coat, said device having an electrical terminal connected to said circuit and extending through and beyond the surface of said encapsulating coat, in which said terminal comprises a wafer in contact with said circuit and a post connected to said wafer and extending beyond the outer surface of said layer, said wafer being at least partly embedded in said top coat and having such configuration and properties as to inhibit said terminal and said circuit from sinking through said cover coat during application of said encapsulating coat.

2. An electrical device according to claim 1, wherein said wafer is sufficiently thin and has a sufficiently large area that it will float in said cover coat when said cover coat is in a fluid state.

3. An electrical device according to claim 1 or 2, wherein said wafer includes a raised dome portion into which any gas generated between said wafer and said circuit can expand.

4. An electrical device according to claim 3, wherein said dome portion includes at least one perforation extending therethrough whereby said generated gas can escape from between said wafer and circuit.

5. An electrical device according to claim 1, 2 or 3 wherein said wafer includes a plurality of weakened portions.

6. An electrical device according to any of claims 1 to 5, wherein said encapsulating coat is between 4 and 10 mils thick wherein said wafer is substantially circular and is between 3 and 10 mils thick.

7. An electrical device according to any preceding claim including a substrate on which said electrical device is supported, said substrate including an aperture and said post extending through said aperture.

8. An electrical device according to any preceding claim, wherein said layer is made of a glass or glass-ceramic material.

9. An electrical device as claimed in claim 1, substantially as hereinbefore described with reference to Figs. 1 to 4, Figs. 1,2,5 and 6, Fig. 7 or Figs. 1,2 and 8 of the accompanying drawings.

10. A method of connecting an electrical terminal to a thin film electrical circuit which circuit is to be encapsulated within a layer of dielectric protective material, comprising the steps of providing a cover coat of said material, applying said thin film electrical circuit on top of said cover coat, connecting a terminal comprising a wafer and a post to said circuit, with said wafer being in contact with said circuit, and applying an encapsulating coat of said material over said circuit and cover coat and at least partly over said wafer, to encapsulate said circuit within said material, said wafer having such configuration and properties as to inhibit said terminal and said circuit from sinking through said cover coat during application of said encapsulating coat.

11. A method of connecting an electrical terminal according to claim 10, wherein said pre-

venting step comprises forming said wafer sufficiently large and sufficiently thin that said terminal will float in said cover coat when said cover coat is in a fluid state.

12. A method of connecting an electrical terminal according to claim 10 or 11, wherein said preventing step comprises forming said wafer with a raised dome portion to allow any gas generated between said circuit and said wafer to expand.

13. A method of connecting an electrical terminal according to Claim 9 or 11 wherein said preventing step includes forming at least one perforation through said wafer to allow any gas generated between said circuit and said wafer to escape from between said wafer and circuit.

14. A method of connecting an electrical terminal to a thin film electrically conductive circuit, substantially as hereinbefore described with reference to Figs. 1 to 4, Figs 1, 2, 5 and 6, Fig 7 or Figs 1, 2, and 8 of the accompanying drawings.

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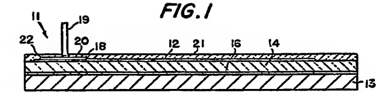
1159390 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1



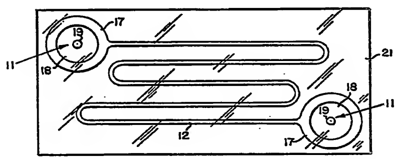


FIG. 2

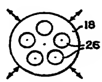


FIG. 3

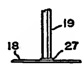


FIG. 4

1159390 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

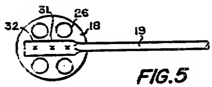


FIG.5

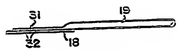


FIG.6

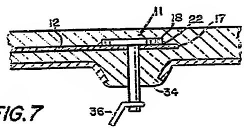


FIG.7

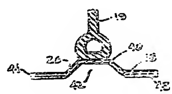


FIG.8

May 2, 1961 C. M. BROWNE 2,982,934

ELECTRICALLY CONDUCTING GLASS UNIT

Filed Aug. 27, 1956

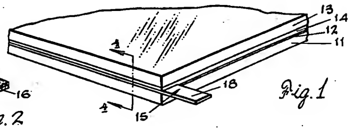


Fig. 1

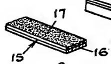


Fig. 2

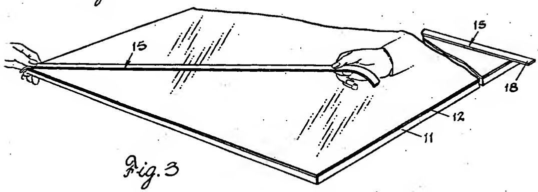


Fig. 3

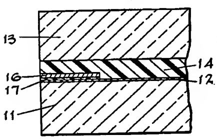


Fig. 4

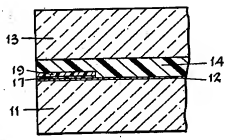


Fig. 5

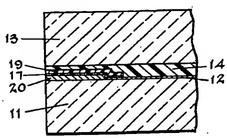


Fig. 6

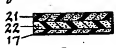


Fig. 7

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